US008090222B1

(12) **United States Patent**
Baluja et al.

(10) **Patent No.: US 8,090,222 B1**
(45) **Date of Patent: Jan. 3, 2012**

(54) **SELECTION OF AN IMAGE OR IMAGES MOST REPRESENTATIVE OF A SET OF IMAGES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1062 days.

(21) Appl. No.: **11/560,246**

(22) Filed: **Nov. 15, 2006**

(51) **Int. Cl.**
G06K 9/54 (2006.01)
G06F 7/00 (2006.01)

(52) **U.S. Cl.** **382/305**; 707/723

(58) **Field of Classification Search** 382/159, 382/162, 305, 312, 218, 219, 224; 381/312; 707/6–7, 100, 706–708, 713, 723, 726, 729, 707/731, 748; 434/362
See application file for complete search history.

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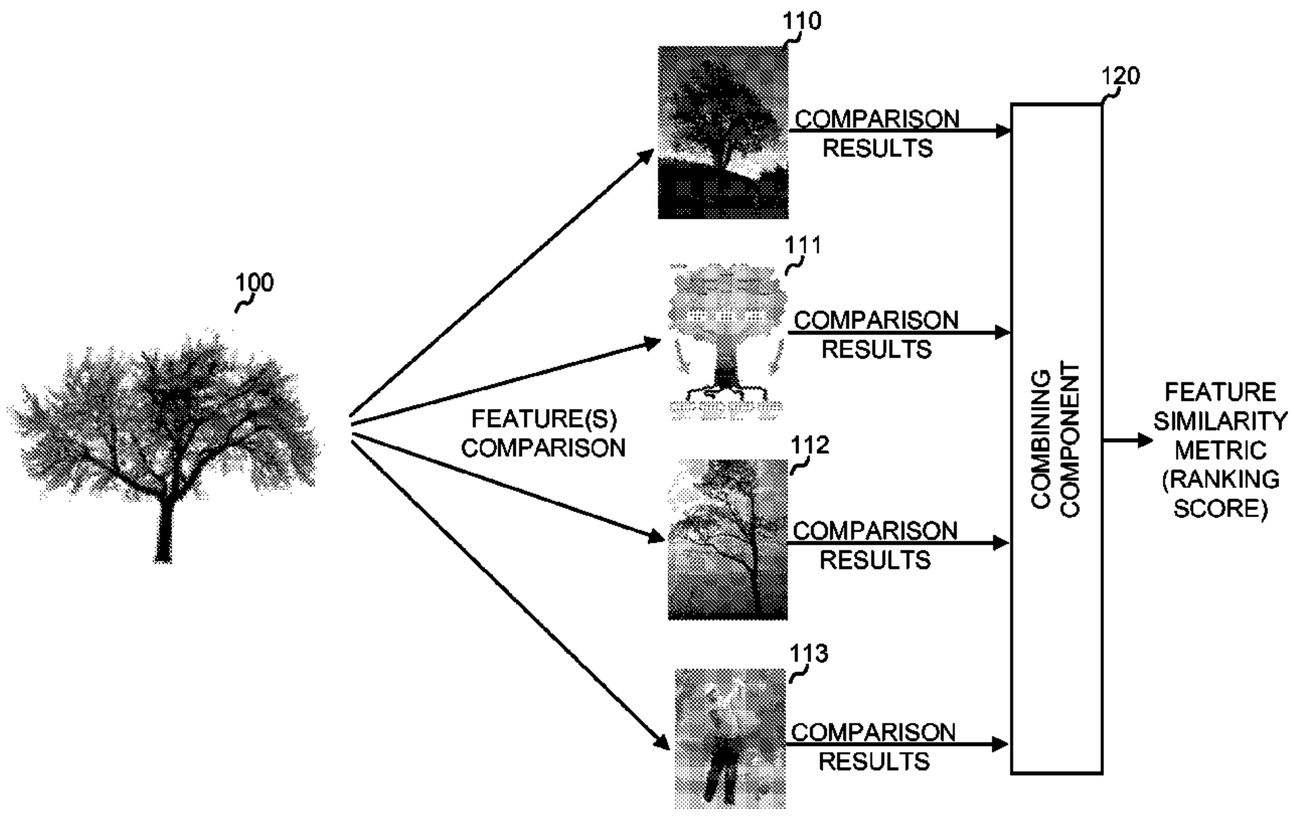
(57) **ABSTRACT**

Implementations consistent with the principles described herein relate to ranking a set of images based on features of the images determine the most representative and/or highest quality images in the set. In one implementation, an initial set of images is obtained and ranked based on a comparison of each image in the set of images to other images in the set of images. The comparison is performed using at least one predetermined feature of the images.

58 Claims, 7 Drawing Sheets



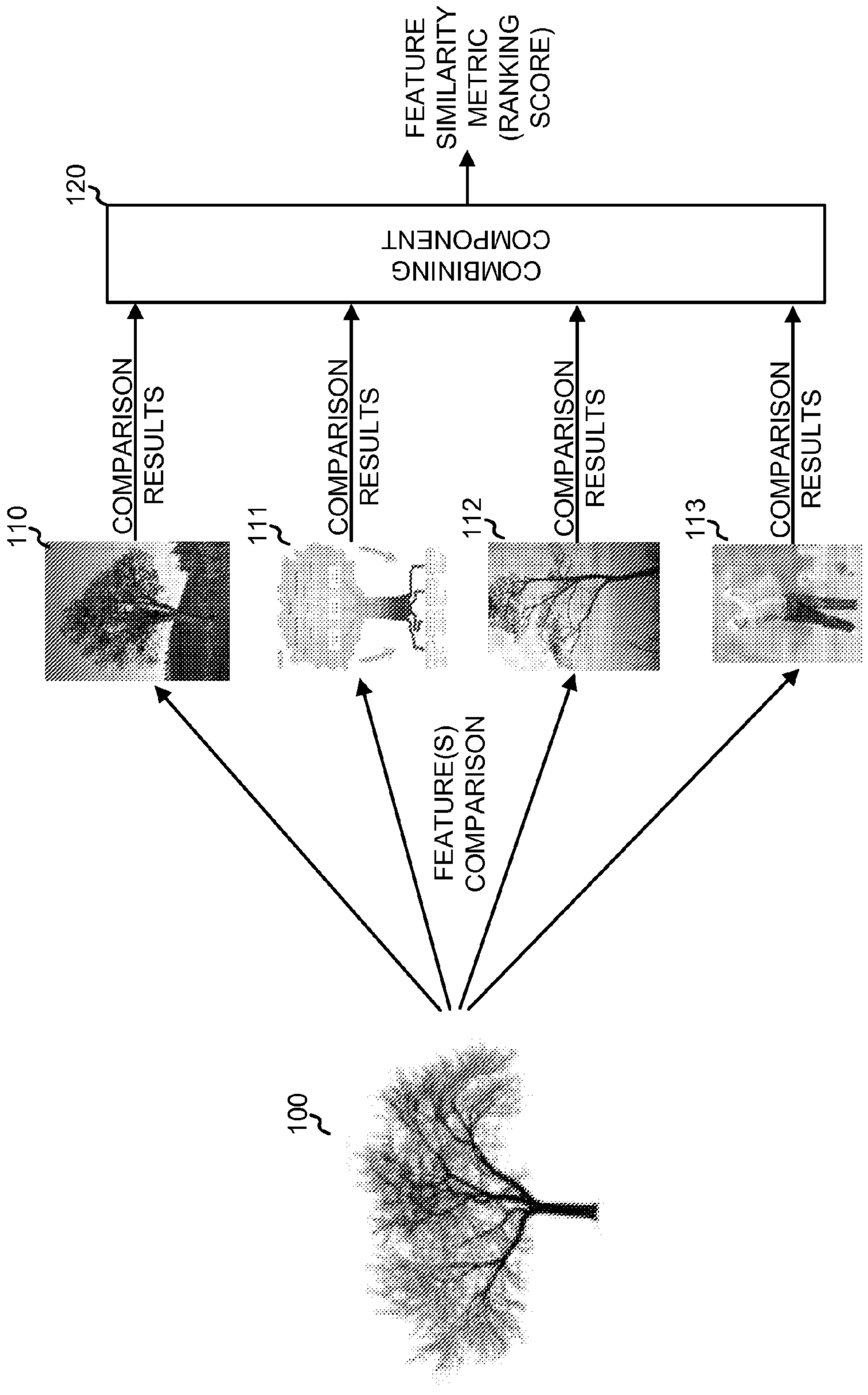

FEATURE SIMILARITY METRIC (RANKING SCORE)
120
COMBINING COMPONENT
COMPARISON RESULTS
COMPARISON RESULTS
COMPARISON RESULTS
COMPARISON RESULTS
110
111
112
113
FEATURE(S) COMPARISON
100

FIG. 1

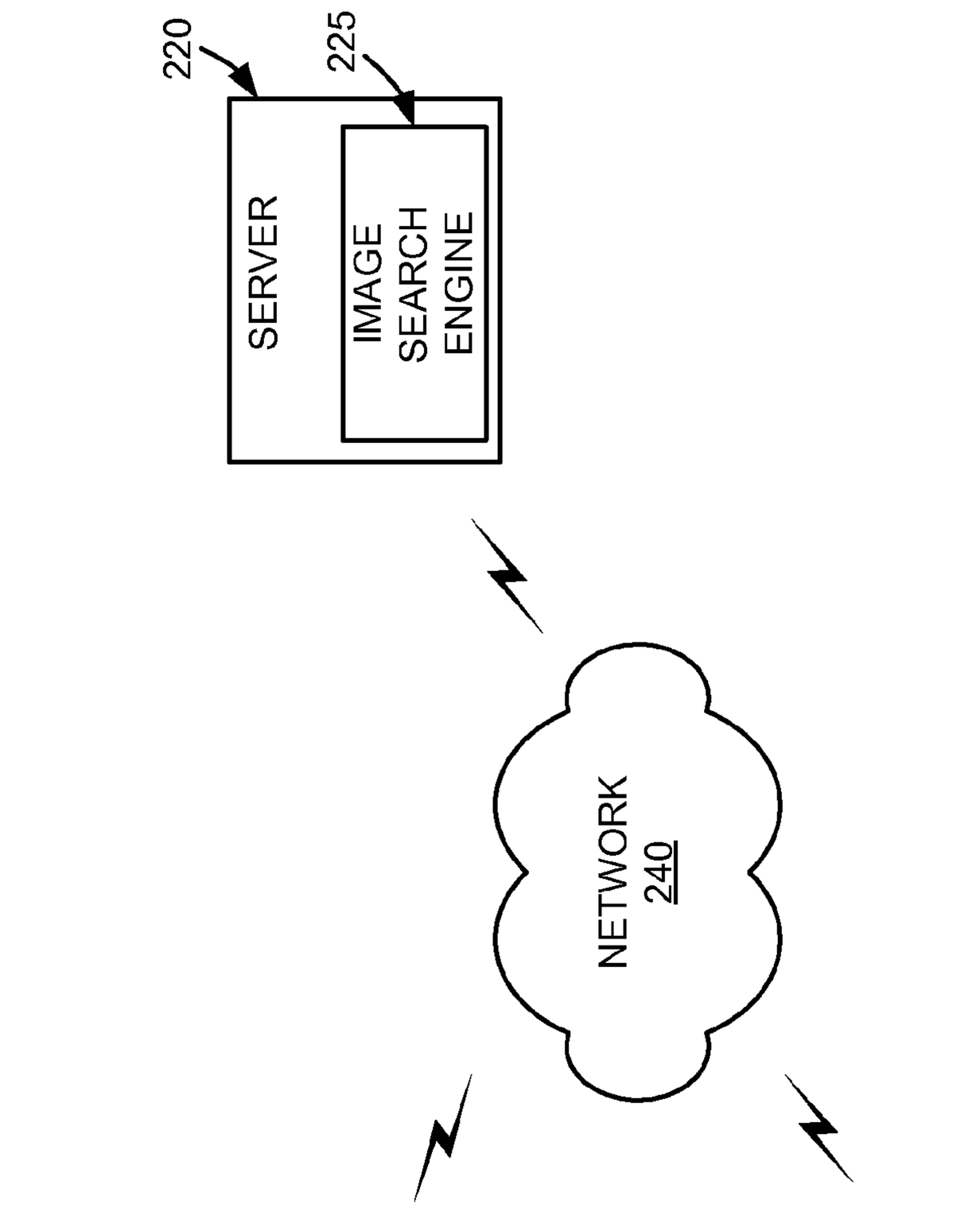

200
CLIENT
210
CLIENT
210
NETWORK
240
SERVER
220
IMAGE SEARCH ENGINE
225

FIG. 2

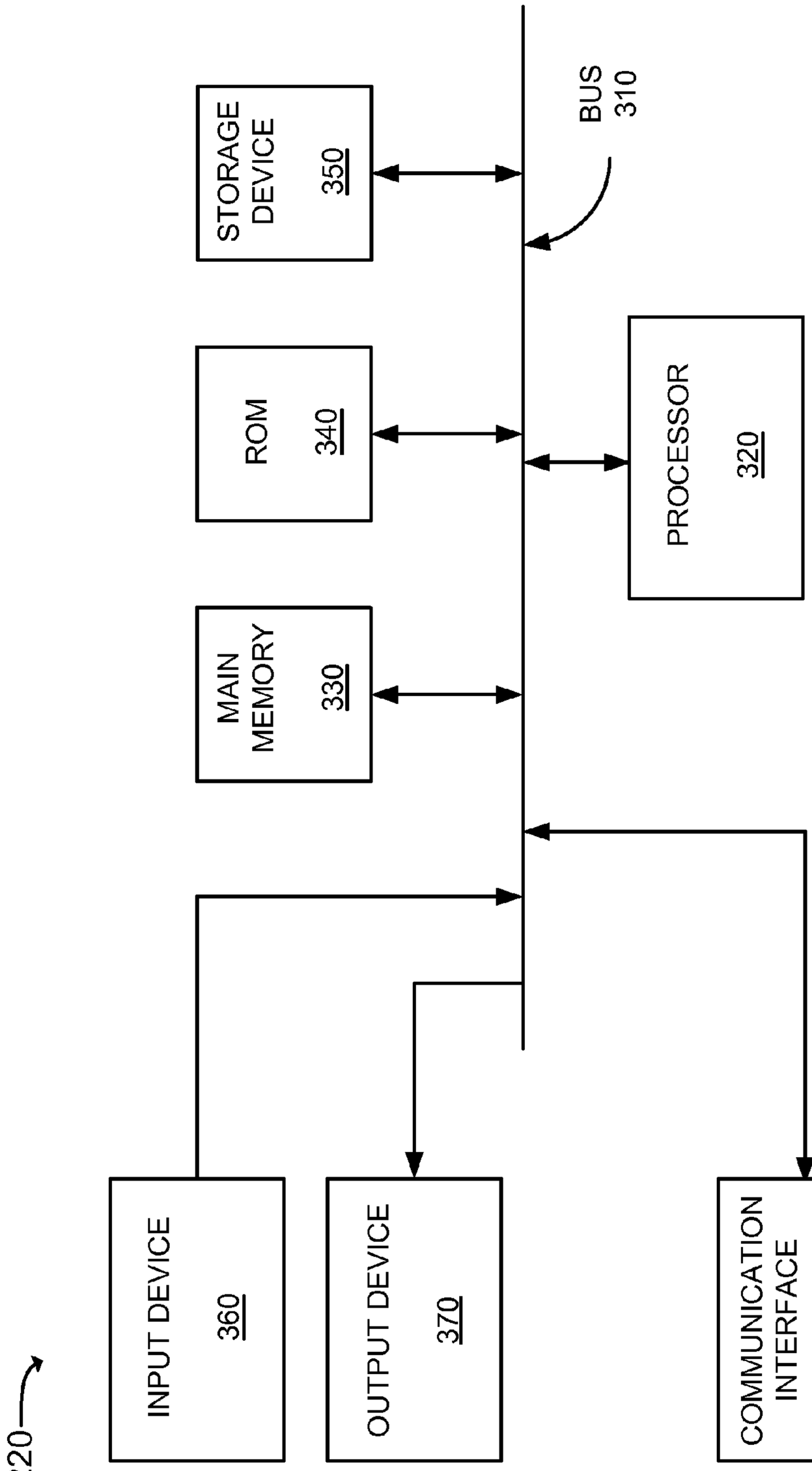

210/220
STORAGE DEVICE 350
BUS 310
ROM 340
PROCESSOR 320
MAIN MEMORY 330
INPUT DEVICE 360
OUTPUT DEVICE 370
COMMUNICATION INTERFACE 380

FIG. 3

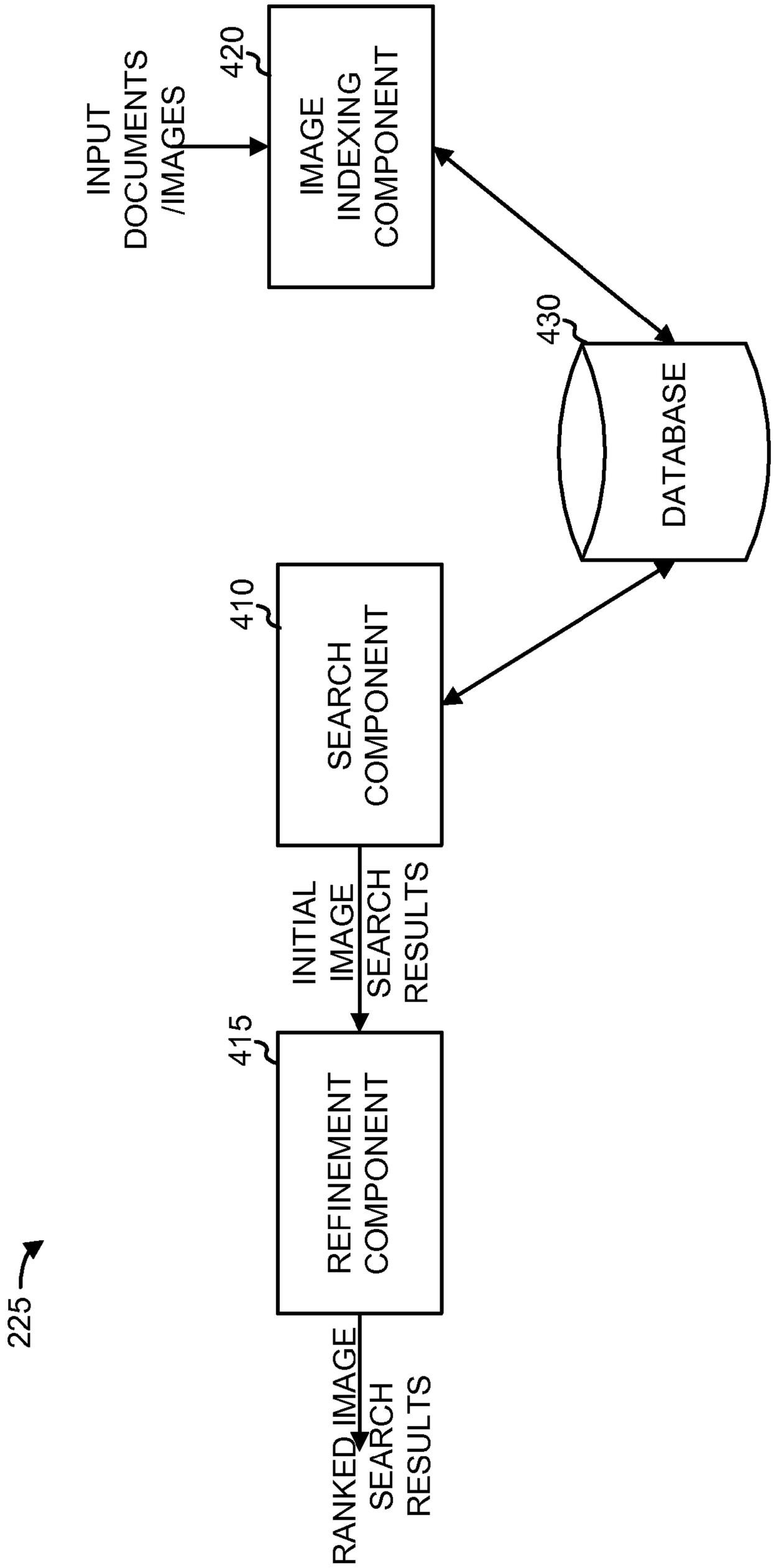

INPUT DOCUMENTS /IMAGES
420
IMAGE INDEXING COMPONENT
430
DATABASE
410
SEARCH COMPONENT
INITIAL IMAGE SEARCH RESULTS
415
REFINEMENT COMPONENT
RANKED IMAGE SEARCH RESULTS
225

FIG. 4

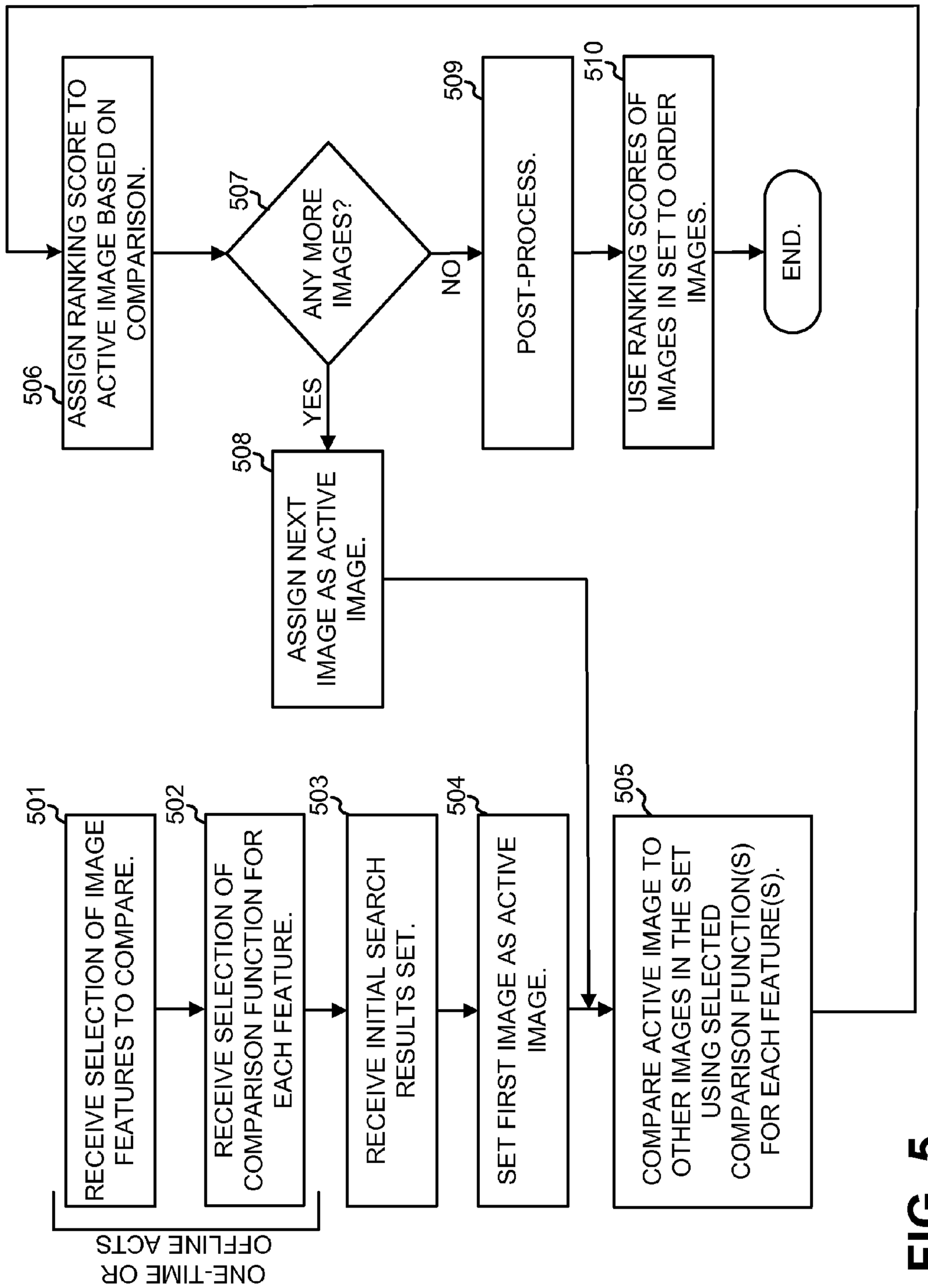

ONE-TIME OR OFFLINE ACTS
501
RECEIVE SELECTION OF IMAGE FEATURES TO COMPARE.
502
RECEIVE SELECTION OF COMPARISON FUNCTION FOR EACH FEATURE.
503
RECEIVE INITIAL SEARCH RESULTS SET.
504
SET FIRST IMAGE AS ACTIVE IMAGE.
505
COMPARE ACTIVE IMAGE TO OTHER IMAGES IN THE SET USING SELECTED COMPARISON FUNCTION(S) FOR EACH FEATURE(S).
506
ASSIGN RANKING SCORE TO ACTIVE IMAGE BASED ON COMPARISON.
507
ANY MORE IMAGES?
YES
NO
508
ASSIGN NEXT IMAGE AS ACTIVE IMAGE.
509
POST-PROCESS.
510
USE RANKING SCORES OF IMAGES IN SET TO ORDER IMAGES.
END.

FIG. 5

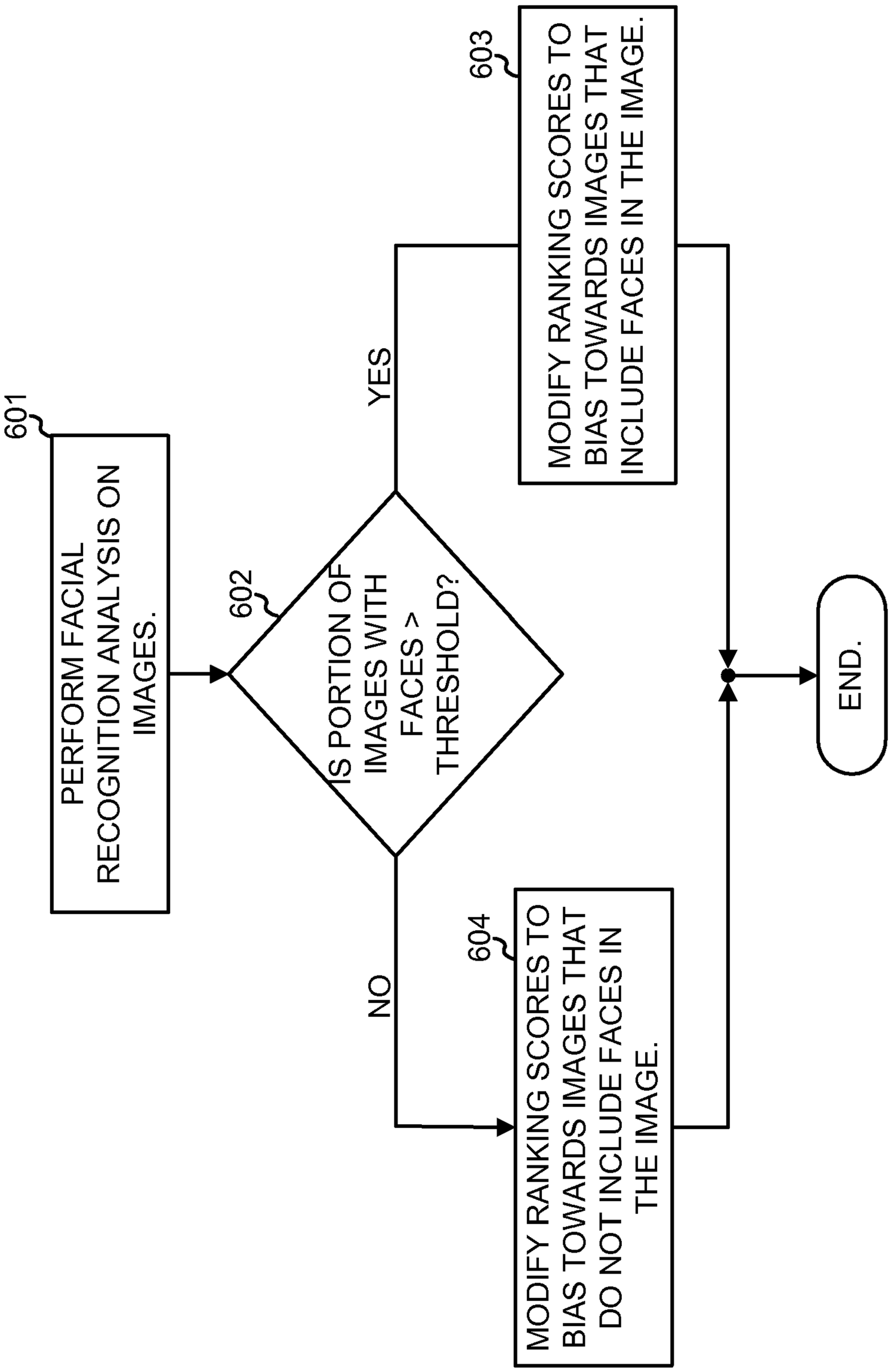

601
PERFORM FACIAL RECOGNITION ANALYSIS ON IMAGES.
602
IS PORTION OF IMAGES WITH FACES > THRESHOLD?
YES
603
MODIFY RANKING SCORES TO BIAS TOWARDS IMAGES THAT INCLUDE FACES IN THE IMAGE.
NO
604
MODIFY RANKING SCORES TO BIAS TOWARDS IMAGES THAT DO NOT INCLUDE FACES IN THE IMAGE.
END.

FIG. 6

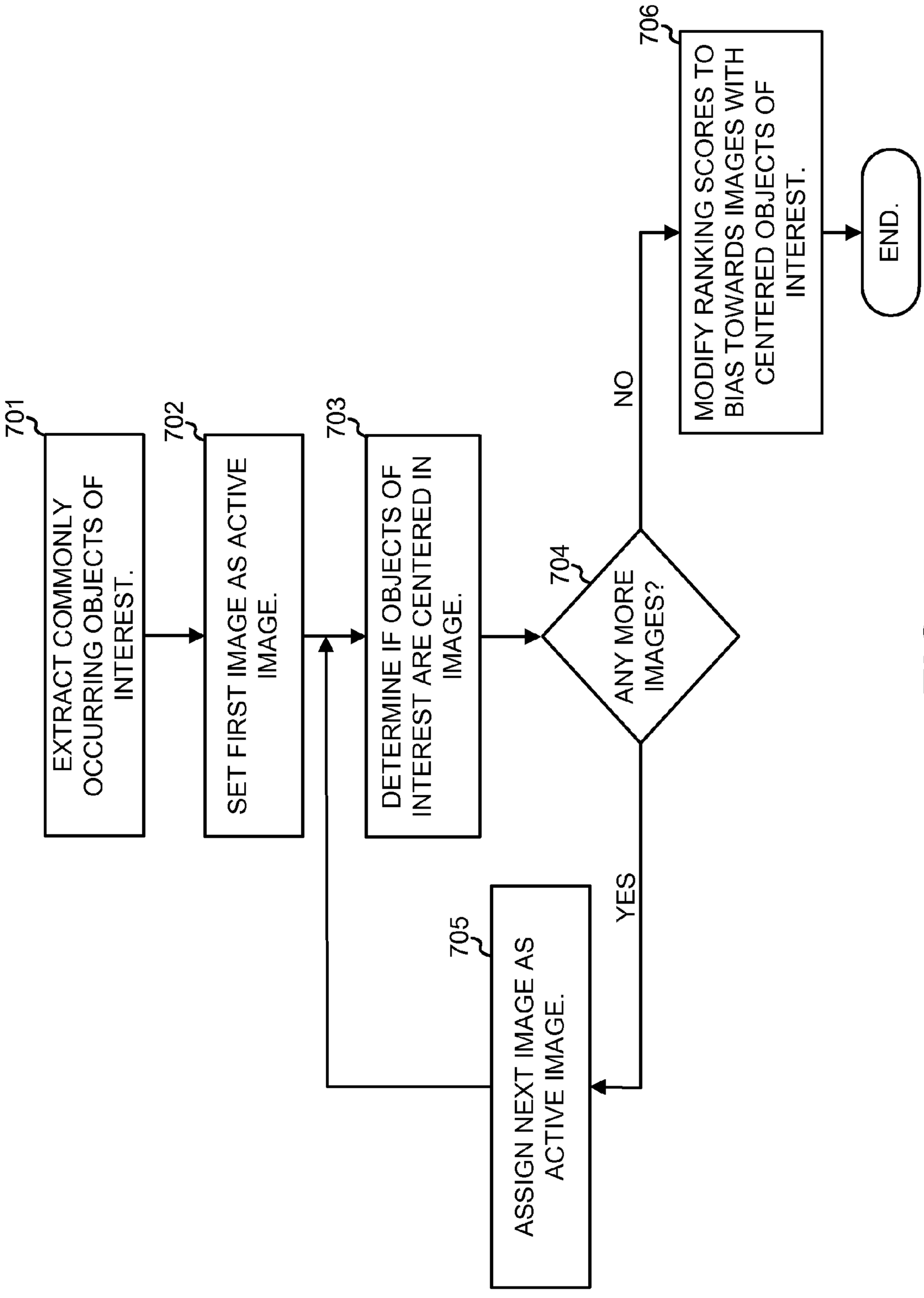

701
EXTRACT COMMONLY OCCURRING OBJECTS OF INTEREST.
702
SET FIRST IMAGE AS ACTIVE IMAGE.
703
DETERMINE IF OBJECTS OF INTEREST ARE CENTERED IN IMAGE.
704
ANY MORE IMAGES?
NO
706
MODIFY RANKING SCORES TO BIAS TOWARDS IMAGES WITH CENTERED OBJECTS OF INTEREST.
END.
YES
705
ASSIGN NEXT IMAGE AS ACTIVE IMAGE.

FIG. 7

SELECTION OF AN IMAGE OR IMAGES MOST REPRESENTATIVE OF A SET OF IMAGES

BACKGROUND

A. Field of the Invention

Implementations described herein relate generally to information retrieval and, more particularly, to improving results of image search engines.

B. Description of Related Art

The World Wide Web ("web") contains a vast amount of information. Search engines assist users in locating desired portions of this information by cataloging web pages. Typically, in response to a user's request, the search engine returns references to documents relevant to the request.

One type of search engine is an image search engine. An image search engine, such as a web-based image search engine, catalogs images from the web. Typically, the image search engine may associate text, such as text that occurs near a particular image, with the image. The text associated with the images may then be searched using conventional keyword based search queries to locate images relevant for the search.

When a user enters a search query for images in an image search engine, the search engine may return hundreds of results (e.g., images or links to images). The large number of potentially relevant results can be daunting for the user. Additionally, because the relevancy of the results may be primarily determined based on text associated with the image, such as by text near the image in a web page, the image itself may not match the search or may be of relatively low quality. For example, a search for "Eiffel Tower" may result in some images that include the Eiffel Tower while others may not. Of the images that contain the Eiffel Tower, some may be images taken at odd poses or odd croppings of the Eiffel Tower, or the Eiffel Tower may not be the main focus of the image (for example, the image may primarily be a picture of a person standing at the base of the Eiffel Tower, with the Eiffel Tower only minimally visible in the background).

It is a goal of an image search engine to return relevant and high quality images to the user. Accordingly, it would be desirable to more effectively determine the quality of images returned to the user.

SUMMARY

One aspect is directed to a method of providing images. The method may include obtaining an initial set of images; ranking the initial set of images based on a comparison of each image in the set of images to other images in the set of images, the comparison being performed using at least one predetermined feature of the images; selecting at least one of the images in the initial set of images based on the ranking; and providing the selected images or links to the selected images to a user.

Another aspect is directed to a computer-implemented method of ranking images. The method may include receiving selection of an image feature to use in ranking the images; receiving selection of a comparison function to use for the image feature; receiving an initial set of images; comparing the selected image feature for a first image in the set of images to other images in the set of images using the comparison function; and generating a ranking score for the first image, the ranking score quantifying how much the first image is representative of the set of images.

Yet another aspect is directed to a system comprising a server connected to a network to receive a search query from a user via the network. The server may include at least one processor; a database to store descriptive text of images in a corpus; and a memory operatively coupled to the processor. The memory may store program instructions that when executed by the processor, cause the processor to generate an initial set of images relevant to the search query based on a matching of terms in the search query to the descriptive text stored in the database; generate a ranking score for each of the images in the generated set of images based on comparisons of features associated with each of the images to corresponding features in other images of the set of images; and return a result set of images or links to images to the user, the order of the images in the result set being determined at least in part by the ranking scores for each of the images.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate one or more embodiments of the invention and, together with the description, explain the invention. In the drawings,

FIG. **1** is a diagram providing a conceptual overview of concepts described herein;

FIG. **2** is an exemplary diagram of a network in which implementations described herein may be implemented;

FIG. **3** is an diagram of an exemplary client or server shown in FIG. **2**;

FIG. **4** is a functional block diagram illustrating an implementation of the image search engine shown in FIG. **2**;

FIG. **5** is a flow chart illustrating exemplary operations that may by performed by the refinement component shown in FIG. **4**;

FIG. **6** is a flow chart illustrating exemplary post-processing operations that may be performed based on the use of facial detection techniques; and

FIG. **7** is a flow chart illustrating exemplary operations of an additional possible post-processing technique.

DETAILED DESCRIPTION

The following detailed description refers to the accompanying drawings. The detailed description does not limit the invention.

Overview

Implementations consistent with the principles described herein relate to ranking an initial set of images, such as a set of images returned from a conventional image search engine, to determine the most representative and/or highest quality images in the initial set. Image results returned to a user may be presented in a manner that emphasizes the more representative/higher quality images.

FIG. **1** is a diagram that provides a conceptual overview of concepts described herein. In this example, assume that a user entered the image search query "tree." For simplicity, assume that five images **100** and **110-113** are located in response to this image search using conventional image search techniques in which the search query is compared to text associated with each of images **100** and **110-113** (e.g., text taken from the file name of the image). It can be appreciated that images **100** and **110-112** may be considered appropriate responses to the image query. Image **113** is clearly not an appropriate image. Image **113** may have been included in the

results because, for example, the caption or article associated with the image described a golfer hitting a ball into trees.

Consistent with aspects described herein, one of the images, such as image **100**, may be compared to each of the other images **110-113**. This comparison may be based on features of the images themselves. A number of different possible image features may be used. For example, the feature comparison may be based on intensity or color histograms of the images, edge based features of the images, or other features of the images. The comparison results may be combined, shown by combining component **120** in FIG. **1**, to produce a combined feature similarity metric (also called ranking score herein) for image **100**.

Images **110-113** may be processed similarly as image **100** to obtain a feature similarity metric for each of images **110-113**. Images **100** and **110-113** may then be ranked based on these feature similarity metrics. Ideally, images **100**, **110**, and **112** would have the highest similarity ranks and would thus be considered the most representative and/or highest quality images. Image **113** should have the lowest similarity rank and may be considered the least representative and/or lowest quality image.

Images **100** and **110-113** may be presented to the user in a visual order based on their similarity ranks. Additionally or alternatively, low ranking ones of images **100** and **110-113** may be removed from the set of images presented to the user.

Exemplary Network Overview

FIG. **2** is an exemplary diagram of a network **200** in which implementations described herein may be implemented. Network **200** may include multiple clients **210** connected to a server **220** via a network **240**. Network **240** may include a local area network (LAN), a wide area network (WAN), a telephone network, such as the Public Switched Telephone Network (PSTN), an intranet, the Internet, or a combination of networks. Two clients **210** and one server **220** have been illustrated as connected to network **240** for simplicity. In practice, there may be more clients and/or servers. Also, in some instances, a client may perform one or more functions of a server and a server may perform one or more functions of a client.

A client **210** may include a device such as a wireless telephone, a personal computer, a personal digital assistant (PDA), a lap top, or another type of computation or communication device, a thread or process running on one of these devices, and/or an object executable by one of these devices. Server **220** may include a server device that processes, searches, and/or maintains documents and images in a manner consistent with the principles of the invention. Clients **210** and server **220** may connect to network **240** via wired, wireless, or optical connections.

Server **220** may include an image search engine **225** usable by clients **210**. In general, in response to a client request, image search engine **225** may return images to the client that are relevant to the client requests.

Exemplary Client/Server Architecture

FIG. **3** is an diagram of an exemplary client **210** or server **220**. Client/server **210/220** may include a bus **310**, a processor **320**, a main memory **330**, a read only memory (ROM) **340**, a storage device **350**, an input device **360**, an output device **370**, and a communication interface **380**. Bus **310** may include conductors that permit communication among the components of client/server **210/220**.

Processor **320** may include a processor(s), a microprocessor(s), or processing logic that interpret and execute instructions. Main memory **330** may include a random access memory (RAM) or another type of dynamic storage device that stores information and instructions for execution by processor **320**. ROM **340** may include a conventional ROM device or another type of static storage device that stores static information and instructions for use by processor **320**. Storage device **350** may include a magnetic and/or optical recording medium and its corresponding drive.

Input device **360** may include one or more mechanisms that permit a user to input information to client/server **210/220**, such as a keyboard, a mouse, a pen, voice recognition and/or biometric mechanisms, etc. Output device **370** may include one or more mechanisms that output information to the user, including a display, a printer, a speaker, etc. Communication interface **380** may include any transceiver-like mechanism that enables client/server **210/220** to communicate with other devices and/or systems. For example, communication interface **380** may include mechanisms for communicating with another device or system via a network, such as network **240**.

As will be described in detail below, server **220** may implement image search engine **225**. Image search engine **225** may be stored in a computer-readable medium, such as memory **330**. A computer-readable medium may be defined as one or more physical or logical memory devices.

The software instructions defining image search engine **225** may be read into memory **330** from another computer-readable medium, such as data storage device **350**, or from another device via communication interface **380**. The software instructions contained in memory **330** may cause processor **320** to perform processes that will be described later. Alternatively, hardwired circuitry or other logic may be used in place of, or in combination with, software instructions to implement processes consistent with the invention. Thus, embodiments described are not limited to any specific combination of hardware circuitry and software.

Image Search Engine **225**

FIG. **4** is a functional block diagram that illustrates an implementation of image search engine **225**. Image search engine **225** may include a search component **410**, a refinement component **415**, an image indexing component **420**, and a database **430**. In general, image indexing component **420** may receive input documents, such as HTML web pages retrieved from the web, and parse the input documents for text and images that are to be included in potential results of search engine **225**. In one implementation, image indexing component **420** may store images, or links to images, and image descriptive text in database **430**.

Database **430** generally stores a collection of data. Database **430** may be implemented as, for example, a relational or non-relational database capable of storing and accessing data. Database **430** may be implemented on a single computing device or distributed across many computing devices and/or storage devices.

Search component **410** may receive user search queries, such as from clients **210**, search database **430** for results based on the search queries, and generate relevant results (i.e., images or links to images) based on a comparison of the search query to the descriptive text for the images that are stored in database **430**. In other words, search component **410** may generally match terms in the search query to the descriptive text associated with the images.

Consistent with aspects described herein, the initial search results from search component **410** may be processed by

refinement component **415**. Refinement component **415** may generally operate to rank the initial search results based on features of the images. Ideally, refinement component **415** will rank the image search results returned by search component **410** so that the images that are most representative of the initial image search results are ranked higher than less representative or lower quality images. The rankings generated by refinement component **415** may be used, for example, to identify the most representative image corresponding to the search query.

One of ordinary skill in the art will recognize that although image search engine **225** is illustrated as containing search component **410**, refinement component **415**, image indexing component **420**, and database **430**, these elements may be physically implemented on different computing devices and may only be loosely coupled to one another. In some implementations, image indexing component **420** may be thought of as being essentially separate from the search component and refinement component portion of search engine **225**, in which image indexing component **420** receives and processes input documents/images independently of search component **410** and refinement component **415**.

Refinement Component **415**

Refinement component **415** will now be described in additional detail. FIG. **5** is a flow chart illustrating exemplary operations that may by performed by refinement component **415**. In general, as was briefly mentioned above, refinement component **415** compares images in a set of images to one another on an image feature basis. Based on the comparison, refinement component **415** may rank the images so that images more representative of the set move to the top of the ranking.

A number of different image features may be used to compare the images. The particular image features to use may be decided ahead of time or offline by an administrator.

Refinement component **415** may receive the selection of which features to use (act **501**). Examples of image features that may be used include image features based on, for example, intensity, color, edges, texture, wavelet based techniques, or other aspects of the image. For example, regarding intensity, each image may be divided into small patches (e.g., rectangles, circles, etc.) and an intensity histogram computed for each patch. Each intensity histogram may be considered to be a feature for the image. Similarly, as an example of a color-based feature, a color histogram may be computed for each patch (or for different patches) within each image. A color histogram can be similarly computed to obtain a possible color-based histogram. The color histogram may be calculated using any known color space, such as the RGB (red, green, blue) color space, YIQ (luma (Y) and chrominance (IQ)), or another color space.

Histograms can also be used to represent edge and texture information. For example, histograms can be computed based on patches of edge information or texture information in an image. For wavelet based techniques, a wavelet transform may be computed for each patch and used as an image feature.

The features discussed above represent an exemplary list of possible image features that may be used. Other image features, such as features identified using the known Scale-Invariant Feature Transform (SIFT) may be used.

In some implementations, to improve computation efficiency, features may be computed only for certain areas within images. For example, "objects of interest" within an image may be determined and image features may only be computed for the objects of interest. For example, if the image feature being used is a color histogram, a histogram may be computed for each patch in the image that includes an object of interest. Objects of interest within an image can be determined in a number of ways. For example, for color, objects of interest may be defined as points where there is high variation in color (i.e., areas where color changes significantly). In general, objects of interest can be determined mathematically in a variety of ways and are frequently based on determining discontinuities or differences from surrounding points. The SIFT algorithm is an example of one technique for locating objects of interest.

Additionally, in some implementations, the various features described above may be computed using different image scales. For example, an image can be examined and features computed in its original scale and then features may be successively examined at smaller scales. Additionally or alternatively, features may be selected as features that are scale invariant or invariant to affine transformations. The SIFT techniques, for example, can be used to extract distinctive invariant objects from images. The extracted objects are invariant to image scale and rotation.

For each feature that is to be used, a comparison function may be selected. A number of different comparison functions may be used to compare images. The particular comparison function to use may be decided ahead of time or offline by an administrator. Refinement component **415** may receive the selection of the comparison functions (act **502**).

In general, a comparison function may operate to generate a value defining a similarity between a particular feature computed for two images. As an example of a possible comparison function, consider a simple histogram comparer function, which is described in pseudo-code in Table I, below. As shown in Table I, the histogram comparer function returns a value that is the sum of the absolute values of the differences between corresponding bins in the input histograms. Smaller values returned from this function indicate greater similarity between the input histograms.

TABLE I

```
Compare_histogram_type_features(histogram1,histogram2)
  Difference = 0;
  For all bins, b, in histogram:
    Difference = Difference + |histogram1 [b] –
    histogram2 [b] |
Return(Difference).
```

The histogram comparer function is exemplary. It can be appreciated that other comparison functions can be used to compare histograms. For example, squared differences may be used rather than absolute differences, bin correlations may be taken into account instead of absolute differences, or percent differences may be used instead of absolute differences. Additionally, for image features other than those based on histograms, different comparison functions may, of course, be used.

The selection of the image features to use and the comparison functions to use (acts **501** and **502**) may be performed offline or in non-runtime operation. For example, an administrator may initially design or configure refinement component **415** to use one or more image features and one or more comparison functions. After these initial acts, refinement component **415** may function in a runtime mode (acts **503**-**510**) to rank a set of input images, such as images returned in an initial image search result set from search component **410**.

In one possible implementation, the selection of image features to use and the comparison functions to use (acts **501** and **502**) may define a set of possible image features and

comparison functions. During runtime operation, the set of possible image features and comparison functions may be dynamically narrowed. For example, the number of matches for a feature across the images for that feature may be used as a measure as to whether the feature is interesting. Assume, for instance, that the user query "black and white pictures of the london tower" initially generated a number of black and white images. With this set of images, using a color histogram as a feature is not likely to be very helpful. However, other features, such as edge-based features, may play a more important part as they may be more distinguishing. A number of techniques may be used to determine whether a feature is interesting for a set of images, such as techniques based on the variation, distribution, or entropy in the responses across images for a feature.

Refinement component **415** may begin runtime operation by receiving an initial image search result set (act **503**). For example, in response to an image search query from a user, search component **410** may return an initial set of images, or links to images, using existing techniques based on matching terms in the search query to terms associated with each image. Refinement component **415** may receive the top N image hits (for example, N may be 1000) from search component **410**.

Refinement component **415** may set the first received image as the active image (act **504**). The active image may then be compared to each other image in the set of images (act **505**). The comparison may be based on the image features from act **501** and may be performed using the comparison functions from act **502**.

An exemplary implementation of act **505** is shown in pseudo-code in Table II, below. In Table II, the final feature similarity metric (ranking score) is tabulated in the variable "image_score."

TABLE II

```
image_score = 0
For each feature F_i of active image i:
  For each image j (where j is not i):
    For each feature F_j of image j that is of type F_i
      same_feature = compare_features(F_i, F_j)
      if same feature < Threshold (e.g., 0.05, or a value that
          indicates the features are close or very
          close)
      image_score = image score + 1
```

In the implementation of act **505** shown in Table II, each feature F_i of the active image is compared with every feature F_j of image j that is the same feature type. In other words, if F_i is a color histogram then the comparison is performed with the color histogram features of image j, if F_i is an edge histogram then the edge histogram features of image j are compared, etc.

Refinement component **415** may assign a ranking score to the active image based on the comparison of act **505** (act **506**). For example, the "image_score" variable (see Table II) indicates how often the features in image i appear in other images and, in this implementation, represents the feature ranking score assigned to the active image. In this implementation, image_score was simply incremented whenever two features were found that were sufficiently similar and image_score was calculated across all features and all other images j. In other implementations, the ranking score may be calculated in other ways, such as by summing or combining the raw values returned by the comparison function (called "compare_features" in Table II). In general, the ranking score may be designed so that more similar image features will contribute more significantly to the ranking score. Also, in the operations shown in Table II, each image feature is weighted equally (i.e., image_score is incremented by one for each similar feature). In some implementations, different features may be weighted differently. For instance, color-based features may be less important than intensity or edge-based features. Accordingly, image_score may be incremented by one for matching color-based features and by more than one for matching intensity or edge-based features.

Acts **505** and **506** may be repeated for each image in the initial results set (acts **507** and **508**) to thus obtain a ranking score for each image in the initial results set.

Acts **505-508** can be relatively computationally expensive, as it requires N^2 comparisons among the N images, and for each comparison, $M_i * M_j$ feature comparisons, for M_i and M_j local features in each image. Techniques are known that may potentially accelerate this type of operation. For example, one such technique is described in the publication "The Pyramid Match Kernel: Discriminative Classification with Sets of Image Features," K. Grauman et al., Proceedings of the IEEE International Conference on Computer Vision, Beijing, China, October 2005.

Additionally, it can be appreciated that to further increase run-time processing performance, the features used for each of the images may be pre-computed ahead of time and stored, for instance, in database **430**. Additionally, for common search queries, not only can the features for each of the images be pre-computed, but the comparisons of the features can also be pre-calculated. In other words, for common search queries, acts **503-509** can be performed ahead of time and the ranking scores may be stored.

Post-processing may optionally be performed on the images to further refine the ranking scores and/or to eliminate certain images from the set of images (act **509**). A number of possible post-processing operations may be performed.

FIG. **6** is a flow chart illustrating exemplary post-processing operations that may be performed based on the use of facial detection techniques. Refinement component **415** may use facial detection techniques to determine whether an image includes a human face and whether the face (if present) is a dominant feature in the image. Image facial detection techniques are known in the art and can be used to determine whether a human face is present in an image and to locate the face in the image.

Refinement component **415** may perform facial detection analysis on the images in the active image set (act **601**). From this analysis, refinement component **415** may thus determine which images include human faces and where in the images the human faces occur. Refinement component **415** may next determine if the number or portion of images in the set is greater than a threshold (act **602**). For example, assume the threshold is set at 50%. If greater than 50% of the images in the set are determined to have faces, then the image search may be assumed to be a search that was intended to find an image of a person. In this case, refinement component **415** may bias or modify the ranking scores to emphasize the images that include faces (act **603**). For example, images that include faces may have their ranking scores boosted in some manner. Additionally, images that include faces and in which the faces are dominant features of the images (e.g., the face or faces take up significant portion of the image), may be additionally boosted.

On the other hand, if less than the threshold portion of images were determined to include faces, than the image search may be assumed to be a search that was not intended to find images of people. In this case, refinement component **415** may bias or modify the ranking scores to emphasize the images that do not include faces (act **604**).

FIG. **7** is a flow chart illustrating exemplary operations of another possible post-processing technique. In the operations shown in FIG. **7**, images in the set of images may have their ranking scores modified based on whether objects of interest are centered in the image. Consider the situation in which a number of images of the Eiffel Tower are identified in response to an image search query for the Eiffel Tower. Some of the images that include the Eiffel Tower may include the Eiffel Tower as a secondary focus of the image. For instance, the Eiffel Tower may be visible in the distant background while the foreground of the image is dominated by a picture of person. This is not an ideal picture of the Eiffel Tower. The operations shown in FIG. **7** may boost the ranking scores of images that include objects of interest that tend to be centered in the image.

To begin, refinement component **415** may extract commonly occurring objects of interest from the set of images (act **701**). In other words, refinement component **415** may analyze the set of images and determine objects of interest that tend to commonly occur in the set of images. Objects of interest may be determined by examining the configuration of the points of interest as found by using local-feature processing algorithms such as the well-known scale-invariant feature transform (SIFT) algorithm for extracting distinctive features from images. One property of the SIFT algorithm is that objects of interest may be extracted invariant to image scale and rotation.

An image may be set as the active image for the set of images and then it may be determined whether or how much the objects of interest tend to occur in or near the center of the image (acts **702** and **703**). The "centerness" of the objects of interest may be quantified in some way by refinement component **415**, such as, for example, by using a scale from zero to one, where zero indicates that there are no objects of interest near the center of the image and one indicates objects of interest are centered and dominant in the image. Act **703** may be repeated for each image in the set (acts **704** and **705**).

In some situations, the best image for a particular scene may tend to include objects of interest that are not centered. For example, common images of the Golden Gate Bridge include the two towers that support the bridge. These two towers tend to be identified as objects of interest in images of the Golden Gate Bridge. The towers, however, are frequently not centered in the images of the Golden Gate Bridge. To handle situations such as this, in some implementations, act **703** may be modified so that instead of using the "center" of the image as the target location for objects of interest, the target location may be determined as the location of objects of interest defined by the average location of an object of interest across all images. In general, the target location may be varied to target objects of interest at arbitrary offset (e.g., around the middle of an image, offset in the left third of an image, etc.)

The ranking scores may be biased towards the images in which commonly occurring objects tend to be centered in the image (act **706**). In this manner, images with centered objects of interest will tend to receive higher ranking scores.

Other post-processing operations may be performed in addition to or alternatively to the facial detection and object centering operations. Specifically, other query independent measures of quality may be applied to each image. For example, each image may be examined to determine a metric relating to how much of the image is in focus, how well the colors are distributed within the image, the amount of contrast within the image, etc. Images that are in-focus or that have a good color distribution may have their ranking scores biased upwards.

Referring back to FIG. **5**, refinement component **415** may next order the images in the set based on the ranking scores (act **510**). For example, the images may be sorted based on their ranking scores and the top M (M greater than or equal to one) of the sorted images may be returned to the user as results of an image search. In this manner, the initial set of images are ranked and a subset of the images are selected based on the rankings. Ideally, the order of the sorted set of images will correspond to an image ordering in which the images near the top are the images that are most representative of the images in the initial set.

Although the ranking scores were described above as being calculated in terms of overlap of features between images, in some implementations, the absolute or relative geometric placement of the image features can also be taken into consideration. For example, it may be desirable to emphasize images in which the features of interest tend to be in geometrically similar locations within an image. In addition to geometric placement, image size, orientation, and image scale may also be considered. For instance, it may be desirable to emphasize objects of interest that take up a large relative portion of an image. Additionally, it may be desirable to take into account the amount of clutter in an image that is outside of the object(s) of interest. For example, an image that includes a dominant object of interest and relatively few additional objects of interest may be preferred to another image that includes the dominant object of interest but that also includes a number of other objects.

Additionally, although the initial feature comparison (act **505**) and post-processing functions (act **509**) were described as occurring in different operations, it can be appreciated that in some implementations these operations can be simultaneously taken into account. For instance, the ranking scores for an image may be computed as a weighted sum of the image_score calculation in act **505** and the post-processing operations in act **509**. For example, if a single "in-focus" post processing calculation is performed, the ranking score may be computed as: a*image_score+b*in_focus_score; where a and b represent weighting factors (e.g., a may be selected to be three and b may be selected to be one) and the "in_focus_score" represents the score for the in-focus post-processing operation.

Exemplary Applications

Refinement component **415** has been primarily described in the context of an image search engine in which refinement component **415** may re-rank or re-order a set of images returned from an image search component. The reordered images will tend to be in an order in which more representative images or higher quality images will gravitate to the top of the order. Accordingly, when the images are presented to the user, the first images shown to the user will be the more representative/higher quality images. In the example of FIG. **1**, for instance, images **100**, **110**, and **112** will likely be presented first to the user followed by image **111**. Image **113** may be presented last to the user or may be pruned (removed) from the set of images presented to the user.

Refinement component **415** may be employed in contexts other than a general image search engine. In general, any application in which images are to be ranked or in which a subset of an initial set of images are to be selected may be an application that is appropriate for application of refinement component **415**. For example, in an image search performed by a user using a mobile device, in which the display area is limited, it may be desirable to prune the number of images returned to the user to some small number (e.g., 5).

Refinement component **415** may additionally be used in situations in which it is desirable to find a single most representative image from a set of images. For example, in a product search engine or a news search engine, it may be desirable to display a single image next to a product listing or next to a news article. For a product search engine, for instance, the name of the product may be used as a search query to return an initial set of possible product images. Refinement component **415** may be used as described above to rank the initial set of product images. The single highest ranking product image may be chosen to display next to the product listing. Similarly, for a news article search engine, selected text from the news article may be used as a search query to return an initial set of possible images. Refinement component **415** may be used as described above to rank the initial set of images. The single highest ranking image may be chosen to display next to the news listing.

CONCLUSION

As described above, a set of images are processed to rank the images using techniques that tend to identify images that are of good quality and that are representative of the set of images. The ranking of images in the manner described herein can be useful in a number of possible applications, such as in improving image search results and in identifying a "best" representative image to show to a user.

The foregoing description of exemplary embodiments of the invention provides illustration and description, but is not intended to be exhaustive or to limit the invention to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of the invention.

Moreover, while a series of acts have been described with regard to FIGS. **5-7**, the order of the acts may be varied in other implementations consistent with the invention. Moreover, non-dependent acts may be implemented in parallel.

It will also be apparent to one of ordinary skill in the art that aspects of the invention, as described above, may be implemented in many different forms of software, firmware, and hardware in the implementations illustrated in the figures. The actual software code or specialized control hardware used to implement aspects consistent with the principles of the invention is not limiting of the invention. Thus, the operation and behavior of the aspects of the invention were described without reference to the specific software code—it being understood that one of ordinary skill in the art would be able to design software and control hardware to implement the aspects based on the description herein.

Further, certain portions of the invention may be implemented as "components" or "models" that performs one or more functions. This elements may be implemented as hardware, such as an application specific integrated circuit or a field programmable gate array, software, or a combination of hardware and software.

No element, act, or instruction used in the description of the invention should be construed as critical or essential to the invention unless explicitly described as such. Also, as used herein, the article "a" is intended to include one or more items. Where only one item is intended, the term "one" or similar language is used. Further, the phrase "based on" is intended to mean "based, at least in part, on" unless explicitly stated otherwise.

What is claimed:

1. A method comprising:

obtaining, by one or more processors, an initial set of images;

ranking, by one or more processors, the initial set of images based on a comparison of at least one image in the set of images to other images in the set of images, the comparison being performed using at least one predetermined feature of the images;

modifying, by one or more processors, the ranking of at least one image, in the initial set of images, based on a face being present in the at least one image;

selecting, by one or more processors, at least one of the images in the initial set of images based on the ranking and the modified ranking; and

providing, by one or more processors, the selected at least one of the images, or one or more links to the selected at least one of the images, to a client device.

2. The method of claim **1**, where the initial set of images are obtained based on a comparison of a search query to descriptive text associated with a corpus of images.

3. The method of claim **1**, where the ranking the initial set of images includes:

assigning a ranking score to each of the images in the initial set of images, the ranking score representing a similarity between the predetermined feature of the images.

4. The method of claim **3**, where there is a plurality of predetermined features of the image and where the ranking the initial set of images includes:

comparing each of the predetermined features of a first image to same features in other images of the set of images using a comparison function corresponding to each of the predetermined features; and

increasing the ranking score based on an amount that the comparison indicates that the predetermined features are similar to the same features in other ones of the images.

5. The method of claim **3**, where the selecting at least one of the images in the initial set of images based on the ranking further includes:

selecting M images, where M is an integer greater than or equal to one, that have the highest ranking scores of the initial set of images.

6. The method of claim **1**, where the at least one predetermined feature includes an image feature based on intensity of the images, color of the images, edges in the images, or texture of the images.

7. The method of claim **1**, further comprising:

determining objects of interest in the set of images, where the comparison of the at least one image in the set of images to other images in the set of images is performed at locations defined by the objects of interest.

8. The method of claim **1**, where at least one predetermined feature includes a feature represented in a histogram and the comparison includes calculating differences between pairs of histograms.

9. The method of claim **1**, where the modifying includes:

boosting the ranking of the at least one image in the initial set of images upwards when the at least one image includes a face and when the initial set of images is determined to be a set of images that was intended to include an image of a person; and

boosting the ranking of the at least one image in the initial set of images upwards when the at least one image does not include a face and when the initial set of images is determined to be a set of images that was not intended to include an image of a person.

10. The method of claim **1**, where ranking the initial set of images includes:

boosting the rankings of each image in the initial set of images when commonly occurring objects in the initial set of images are located at or near a center of the image.

11. The method of claim 1, where ranking the initial set of images includes:

boosting the rankings of each image in the initial set of images when commonly occurring objects in the initial set of images are located at a position defined as an average location at which the commonly occurring objects occur in the set of images.

12. The method of claim 1, where ranking the initial set of images includes:

modifying the rankings of the images in the initial set of images based on a metric relating to how much of the image is in focus or how well colors in the image are distributed.

13. The method of claim 1, where ranking the initial set of images includes:

modifying the rankings of the images in the initial set of images based on a metric relating to how a size of an object of interest in the image relative to the image.

14. The method of claim 13, where ranking the initial set of images includes:

further modifying the rankings of the images based on an amount of clutter in the image outside of the object of interest.

15. The method of claim 1, where the predetermined features of the images are computed offline.

16. The method of claim 1, where the initial set of images are obtained based on a search query and where, for common search queries, the predetermined features of the images and the comparison of the at least one image in the set of images to other images in the set of images is performed offline.

17. The method of claim 1, where selecting the at least one of the images in the initial set of images based on the ranking includes selecting a top ranking image in the initial set of images and where the providing the selected at least one of the images, or one or more links to the selected at least one of the images, to the client device includes providing the top ranking image to the client device in association with a product search or a news article search.

18. The method of claim 1, where the providing the selected images or links to the selected images is performed as a set of image results for an image search engine.

19. A device comprising:

means for obtaining an initial set of images;

means for ranking the initial set of images based on comparisons of the at least one image in the set of images to other images in the set of images, the comparisons being performed using at least one predetermined feature of the images;

means for assigning a ranking score to at least one image in the initial set of images, the ranking score representing similarity between the predetermined features of the images;

means for performing post-processing functions on the ranking scores, the post-processing functions being based on facial detection or object centering techniques;

means for selecting at least one of the images in the initial set of images based on the post-processed ranking scores; and

means for providing the selected at least one of the images, or one or more links to the selected at least one of the images, to a client device.

20. The device of claim 19, where the means for ranking the initial set of images includes:

means for comparing image features based on image intensity, image color, image edges, or image texture.

21. A method comprising:

receiving, by one or more processors, selection of an image feature to use in ranking the images;

receiving, by one or more processors, selection of a comparison function to use for the image feature;

receiving, by one or more processors, an initial set of images;

comparing, by one or more processors, the selected image feature for a first image in the set of images to other images in the set of images using the comparison function;

generating, by one or more processors, a ranking score for the first image, the ranking score quantifying how much the first image is representative of the set of image; and

modifying, by one or more processors, the ranking score based on whether the first image includes a face or whether commonly occurring objects in the set of images are centered in the first image.

22. The method of claim 21, where the comparing and the generating are repeated for each of the other images in the set of images to obtain a plurality of ranking scores.

23. The method of claim 21, where receiving the initial set of images includes:

obtaining the initial set of images based on a comparison of a search query to descriptive text associated with a corpus of images.

24. The method of claim 21, where the receiving the selection of an image feature and the receiving the selection of the comparison function further includes:

receiving a plurality of image features; and

receiving a plurality of comparison functions.

25. The method of claim 21, where the image feature includes:

an image feature based on intensity of the images, color of the images, edges in the images, or texture of the images.

26. The method of claim 21, further comprising:

determining objects of interest in the images, where the selected image feature is performed at locations in the first image of the objects of interest.

27. The method of claim 21, where the selected image feature is represented as a histogram and the comparison function includes calculation of differences between pairs of histograms.

28. The method of claim 21, further comprising:

modifying the ranking score based on a metric relating to how much of the first image is in focus or how well colors in the first image are distributed.

29. A system comprising:

a server connected to a network to receive a search query from a client device via the network, the server including:

at least one processor;

a database to store descriptive text of images in a corpus; and

a memory operatively coupled to the processor, the memory storing program instructions that when executed by the processor, cause the processor to:

generate an initial set of images relevant to the search query based on a matching of terms in the search query to the descriptive text stored in the database,

generate a ranking score for at least one of the images in the generated set of images based on comparisons of features associated with the at least one of the images to corresponding features in other images of the set of images,

boost the ranking score of an image, in the initial set of images, when commonly occurring objects in the initial

set of images are located in at least one of a center of the image or a position in the image defined as an average location at which the commonly occurring object occurs in the set of images, and

return, to the client device, a result set of images, or links to images in the result set of images, ranked in an order based on the generated ranking scores and boosted ranking score.

30. The system of claim **29**, where the features include:

image features based on intensity of the images, color of the images, edges in the images, or texture of the images.

31. The system of claim **30**, where the program instructions additionally cause the processor to:

modify the ranking scores of those images, in the initial set of images, that include a face.

32. The system of claim **31**, where the program instructions additionally cause the processor to:

modify the ranking score of an image in the initial set of images based on a metric relating to how much of the image is in focus or how well colors in the image are distributed.

33. A system comprising:

a server device to:

obtain an initial set of images;

rank the initial set of images based on a comparison of at least one of the images, in the set of images, to other images in the set of images, the comparison being performed using at least one predetermined feature of the images;

modify the ranking of at least one image, in the initial set of images, based on a face being present in the at least one image;

select at least one of the images, in the initial set of images, based on the ranking; and the modified ranking; and

provide the selected at least one of the images, or one or more links to the selected at least one of the images, to a client device.

34. The system of claim **33**, where, when the server device is to obtain the initial set of images, the server device is to:

obtain the initial set of images based on a comparison of a search query to descriptive text associated with a corpus of images.

35. The system of claim **33**, where, when the server device is to rank the initial set of images, the server device is to:

assign a ranking score to the at least one of the images in the initial set of images, the ranking score representing a similarity between the predetermined feature of the images.

36. The system of claim **35**, where the at least one predetermined feature of the images includes a plurality of predetermined features of the images and where, when the server device is to rank the initial set of images, the server device is to:

compare each of the predetermined features of a first image to same features in other images of the set of images using a comparison function corresponding to each of the predetermined features; and

increase the ranking score based on an amount that the comparison indicates that the predetermined features are similar to the same features in other ones of the images.

37. The system of claim **35**, where, when the server device is to select at least one of the images in the initial set of images based on the ranking, the server device is to:

select M images, where M is an integer greater than or equal to one, that have highest ranking scores of the initial set of images.

38. The system of claim **33**, where the at least one predetermined feature includes an image feature based on intensity of the images, color of the images, edges in the images, or texture of the images.

39. The system of claim **33**, where the server device is further to: determine objects of interest in the set of images, where the comparison of the at least one image in the set of images to other images in the set of images is performed at locations defined by the objects of interest.

40. The system of claim **38**, where the at least one predetermined feature includes a feature represented in a histogram and the comparison includes calculating differences between pairs of histograms.

41. The system of claim **33**, where, when the sewer device is to modify the ranking of at least one image, in the initial set of images, based on a face being present in the at least one image, the server device is further to:

boost the ranking of the at least one image in the initial set of images upwards when the at least one image includes a face and when the initial set of images is determined to be a set of images that was intended to include an image of a person; and

boost the ranking of the at least one image in the initial set of images upwards when the at least one image does not include a face and when the initial set of images is determined to be a set of images that was not intended to include an image of a person.

42. The system of claim **33**, where, when the server device is to rank the initial set of images, the server device is to: boost the rankings of each image in the initial set of images when commonly occurring objects in the initial set of images are located at or near a center of the image.

43. The system of claim **33**, where, when the server device is to rank the initial set of images, the server device is to:

boost the rankings of each image in the initial set of images when commonly occurring objects in the initial set of images are located at a position defined as an average location at which the commonly occurring objects occur in the set of images.

44. The system of claim **33**, where, when the server device is to rank the initial set of images, the server device is to:

modify the rankings of the images, in the initial set of images, based on a metric relating to how much of the image is in focus or how well colors in the image are distributed.

45. The system of claim **33**, where, when the server device is to rank the initial set of images, the server device is to:

modify the rankings of the images in the initial set of images based on a metric relating to how a size of an object of interest in the image relative to the image.

46. The system of claim **45**, where, when the server device is to rank the initial set of images, the server device is further to:

further modify the rankings of the images based on an amount of clutter in the image outside of the object of interest.

47. The system of claim **33**, where the server device is to compute the at least one predetermined feature offline.

48. The system of claim **33**, where, when the server device is to obtain the initial set of images, the server device is to obtain the initial set of images based on a search query, and where, for search queries that are received more than a particular number of times within a particular period of time, the server device is to:

rank the initial set of images, based on a comparison of the at least one image in the set of images to other images in the set of images, offline.

49. The system of claim 33, where, when the server device is to select least one of the images in the initial set of images based on the ranking, the server device is to:

select a top ranking image in the initial set of images; and

where, when the server device is to provide the selected at least one of the images, or the one or more links to the selected at least one of the images, to the client device, the server device is to:

provide the top ranking image to the client device in association with a product search or a news article search.

50. The system of claim 33, where the server device is to provide the selected at least one of the images, or one or more links to the selected at least one of the images, to the client device as a set of image results for an image search engine.

51. A system comprising:

a server device to:

receive selection of an image feature to use in ranking the images;

receive selection of a comparison function to use for the image feature;

receive an initial set of images;

compare the selected image feature for a first image, in the set of images, to other images, in the set of images, using the comparison function;

generate a ranking score for the first image, the ranking score quantifying how much the first image is representative of the set of images; and

modify the ranking score based on whether the first image includes a face or whether commonly occurring objects in the set of images are centered in the first image.

52. The system of claim 51, where the server device is to perform the comparing and the generating for each of the other images, in the set of images, to obtain a plurality of ranking scores.

53. The system of claim 51, where, when the server device is to receive the initial set of images, the server device is to:

obtain the initial set of images based on a comparison of a search query to descriptive text associated with a corpus of images.

54. The system of claim 51, where, when the server device is to receive the selection of the image feature and receive the selection of the comparison function, the server device is to:

receive a plurality of image features; and

receive a plurality of comparison functions.

55. The system of claim 51, where the image feature includes:

an image feature based on intensity of the images, color of the images, edges in the images, or texture of the images.

56. The system of claim 51, where the server device is further to:

determine objects of interest in the images, where the selected image feature is examined at locations, in the first image, of the objects of interest.

57. The system of claim 51, where the selected image feature is represented as a histogram and the comparison function includes calculation of differences between pairs of histograms.

58. The system of claim 51, where the server device is further to:

modify the ranking score based on a metric relating to how much of the first image is in focus or how well colors in the first image are distributed.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,090,222 B1
APPLICATION NO. : 11/560246
DATED : January 3, 2012
INVENTOR(S) : Shumeet Baluja et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims:

Column 14, line 14, claim 21, reads "the set of image; and" but should read --the set of images; and--.

Column 15, line 35, claim 33, after "based on the ranking", delete ";".

Column 16, line 14, claim 41, reads "sewer" and should read --server--.

Signed and Sealed this
Twenty-first Day of February, 2012

David J. Kappos
Director of the United States Patent and Trademark Office